Patterning Liquid Flow at the Microscale (Invited)

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To shrink a chemistry laboratory to the size of a microchip may have seemed far-fetched a decade ago. However, revolutionary microfluidic devices ranging from surgical endoscopes and micro-electro-mechanical systems to the commercial ``lab-on-a-chip'' are now capable of analysis and synthesis at the microscale. These devices require transporting volumes of liquid in the picoliter range or smaller through a network of interior channels. Several techniques have been developed to control microscale flow including micromechanical pumping, electrohydrodynamic pumping, electro-osmotic flow, electrowetting and thermocapillary pumping. The majority of these schemes drive continuous streams or liquid droplets through interior channels, which are easily blocked by dust or contaminants, and rely on kilovolt sources to drive the electrokinetic flow. Recent work by Handique et al.. has explored the use of temperature fields to drive droplet movement. We demonstrate a new differential technique, which derives from thermocapillary motion, to flow micro streams or droplets on a selectively patterned surface. Liquid flow is controlled by simultaneously applying a shear stress at the air-liquid surface and a variable surface energy pattern at the liquid-solid interface. Advantages to this open architecture design include direct contact with the vapor phase, reduced friction and no blockage, no electroactive additives, no moving parts and low power consumption. To downsize this technology further, we provide an estimate of the smallest liquid feature transportable by this technique.